DOCUMENT RESUME

ED 224 008 CS 006 937

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TITLE Access and Maintenance of Phonological Codes in Listening and Reading.
INSTITUTION National Inst. of Child Health and Human Development (NIH), Bethesda, Md.; National Science Foundation, Washington, D.C.
PUB DATE May 82
GRANT NIH-HD-16019-01; NSF-IST-80-12439
NOTE 21p.; Revised version of a paper given at the Annual Meeting of the Midwestern Psychological Association (Minneapolis, MN, May 6-8, 1982).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cognitive Processes; Higher Education; *Language Processing; *Language Research; *Listening Comprehension; *Phonology; *Reading Comprehension
IDENTIFIERS *Rhyme Priming

ABSTRACT

Three experiments used "rhyme priming," a methodology in which lexical decisions to a visually presented word are facilitated when the word is preceded by a rhyming word, to investigate the access and maintenance of speech-based codes in sentence comprehension. In these experiments, the pairs were visually dissimilar rhymes, such as "eight-late." In each experiment, one member of the rhyme pair was embedded in a sentence and the other was presented visually for the subject to decide if it fit in the sentence. Control sentence pairs did not rhyme. In experiments 1 and 2, sentences were presented orally, to 48 and 18 college students, respectively. Results of experiment 1 revealed that rhyme priming obtained when the rhyming parts were separated by four but not by seven intervening words, suggesting that the phonological code for the word was initially accessed and then rapidly destroyed. In experiment 2, where parsing demands required that the prime word be held in working memory, rhyme priming obtained even with seven intervening words. In experiment 3, the same materials used in experiment 1 were presented visually to 28 college students, and no rhyme priming effects obtained. The results of the listening studies were encouraging; however, they did not generalize to reading. (JL)

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ED224008

Access and Maintenance of Phonological Codes in Listening and Reading

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This is a revised version of a paper presented at the 1982 Meetings of The Midwestern Psychological Association held in Minneapolis. This research was supported by NSF grant IST 80-12439 and by NIH grant HD 16019-01.

CS006137

Many aspects of the comprehension process require the listener to maintain information in working memory for the purpose of integration with other information. Information must be integrated at the sentence level during parsing and at the discourse level while assigning anaphora, integrating propositions, and drawing inferences.

Numerous researchers have suggested that speech based codes play an important role in maintaining linguistic information in working memory in both listening and reading. Evidence in support of this comes from studies in which irrelevant vocalization is used to block speech coding. For example, Levy (1977) had subjects count while listening or reading sentence triples. Counting interfered with the subjects' ability to detect lexical and semantic changes in a subsequently presented test sentence in the listening but not the reading condition. More recently, however, Levy (1978) and Slowiacek and Clifton (1980) have suggested that blocking speech coding interferes with only higher level discourse processes such as integrating propositions and drawing inferences. Interference occurs in both listening and reading although it is more robust in reading. These results suggest that speech coding is used primarily for discourse level integrative processes.

However another interpretation of these findings has been pointed out by Levy (1977). That is, vocalization maybe a general resource demanding task. If we assume that reading is more resource demanding than listening as Masson and Sala (1978) and others have demonstrated and that discourse level processes are more resource demanding than lower level processes, then a resource explanation would predict the pattern of results obtained by Slowiacek and Clifton (1980).

It thus becomes important to explore other methodologies which might provide converging evidence about the role of speech-based codes in comprehension. "Rhyme priming" may provide one such methodology. Meyer, Schvaneveldt, and Ruddy (1975) demonstrated that lexical decisions to a visually presented word are facilitated when the word is preceded by a rhyming word, for example when pouch is followed by couch. Hillinger (1980) using a lexical decision task and Tanenhaus, Flanigan and Seidenberg (1980) using a color naming (Stroop) task have shown that rhyme priming obtains cross-modally, that is when the prime is spoken and the target is presented visually. The present studies used the rhyme priming methodology to trace the availability of speech-based codes as a function of linguistic structure in listening and reading. Three questions were addressed by these studies. First, will cross-modal rhyme priming obtain when the prime word is embedded in a sentence? Previous demonstrations of rhyme priming have used single word presentation. If rhyme priming obtains this would provide evidence that phonological codes are accessed during comprehension. Secondly, does the availability of speech-based codes vary as a function of linguistic structure.[7] If so, then this would provide evidence about one role of phonological codes during comprehension. Finally, are there differences in the access and maintenance of phonological codes during listening and reading?

Experiment 1

In Experiment 1 a word rhyming with a target word was embedded in a two clause sentence. The rhyme word either occurred in the first or second clause of the sentence and either four or seven words intervened between the rhyme word and the target word.

The clause manipulation was chosen because information in the second clause of a sentence has been shown to be more available than information in the first clause of a sentence (Caplan, 1972; Chang, 1980). According to Bever and Hurtig (1975), this is because information within a clause is maintained in a relatively verbatim form until the clause boundary. The use of speech-based codes may be the mechanism that listeners use to hold onto the verbatim form of words within a clause. If so, then rhyme priming should vary as a function of clause structure. The length variable was included in order that we might trace the time course for the availability of phonological codes. If a speech-based code is used to maintain the words in the clause in working memory, then rhyme priming should vary as a function of clause structure. If, however, rhyme priming occurs merely as an automatic consequence of lexical access and is unaffected by clause structure, then it should only be affected by the number of words intervening between the rhyme word and the target.

Method

Subjects. Forty-eight Wayne State University students served as unpaid subjects.

Materials. The test stimuli were two clause sentences which were constructed from pairs of words such as juice-loose which rhymed but were spelled differently. One member of the pair served as the target while the other member of the pair (the prime word) occurred within the test sentence. Nonrhyming control sentences were generated by replacing the prime word with a nonrhyming word which fit the meaning of the sentence. Sample stimuli are presented in Table 1.

Procedure. Subjects heard the sentences over headphones. Immediately after hearing each sentence the subject made a lexical decision to the target. The target was visually presented. Whether or not the prime and target rhymed was varied. The prime word occurred in either the first or second clause and within each clause there were either four or seven words intervening between the prime and the end of the sentence. Test trials were intermixed with filler and nonword trials in order to reduce strategies. In addition a true-false comprehension question followed the lexical decision on a proportion of the trials. These questions served to insure that the subject listened to the sentences for good comprehension.

Results and Discussion

Overall mean lexical decision times for each of the 8 prime sentence contexts are presented in Table 1. Facilitation for each condition was calculated by subtracting the rhyme from the nonrhyme control and is shown in the last column of the table. Facilitation was obtained only when 4 words intervened between the prime and the target and not when there were 7 intervening words. This is reflected in a significant rhyme X length interaction $F(1,47) = 6.66$, $p < .05$ by subject and by item $F(1,30) = 4.64$, $p < .05$. There were no effects of clause structure.

The results indicated that rhyme priming was affected only by the number of words intervening between the rhyme word and the target and not by clause structure. The results demonstrate that listeners are accessing phonological codes during listening. These codes remain active long enough to facilitate recognition of a rhyming word even with four intervening words. With seven

intervening words the rhyme priming effect has decayed. Thus the results provide some initial information about the duration for which the phonological code for a word remains active.

There were no effects, however, of clause structure. There are at least two possible explanations for why no effects of clause structure obtained. One possibility is that the availability of phonological codes is unaffected by higher-order (i.e., post-lexical) variables. If so, then rhyme priming is of limited usefulness for investigating comprehension processes beyond the lexical level. Nonetheless the fact that phonological codes remain active for at least four words but not seven words may set certain constraints on comprehension. For example, the time course for the decay of phonological codes may set limits on the number of words that subjects can process as a chunk. A second possibility is that phonological codes usually are not actively maintained. However the phonological code for a word may be actively maintained when the comprehension demands of a sentence require that it be. For example, Slowiacek and Clifton (1980) have suggested that parsing demands may sometimes induce subjects to use phonological codes. One such situation may occur when a sentence contains what Frazier and Fodor (1978) have labelled a filler-gap dependency. Consider, a sentence such as:

(1) The gourmet was surprised at which beer the judges awarded the first prize to _____.

In order to comprehend this sentence the listener or reader must hold onto the word beer until he or she can assign it a grammatical role in the following clause. The location or "gap" where the word beer has been moved from is indicated by underlining.

Wanner and Maratsos (1978) suggested that the filler nounphrase is placed in a hold mechanism until the gap is detected. The filler is then inserted into the gap. If speech-based codes are used to maintain the filler phrase in working memory, then rhyme priming ought to obtain to targets rhyming with filler words, until the gap has been detected and filled. Experiment 2 was designed to explore this possibility.

Experiment 2

Method

Subjects. Eighteen Wayne State University students served as unpaid subjects.

Stimulus Materials. Half the test stimuli were sentences containing wh-questions in which the gap occurred between two and four words from the end of the sentence. These sentences were constructed from pairs of rhymes which were spelled differently. One member of the pair served as the target while the other member of the pair occurred in the test sentence (the prime word). Each test sentencee also served as a nonrhyme control sentence. Nonrhyme control sentences were generated by replacing the prime word with another monosyllabic word congruent with the meaning of the sentence.

In the remaining half of the test sentences, the prime word occurred at the end of the sentence. Test sentences in this condition were also generated from dissimilarly spelled pairs of rhymes in the same manner as they were in the wh-conditions.

Procedure. On each trial, subjects heard a sentence (containing the prime) followed 400 msec later by a visually presented target. The subject's

task was to decide as quickly as possibly whether or not the letter string (target) was a word. Test trials were intermixed with filler and nonword trials in order to reduce strategies. In addition, a true-false comprehension question followed the lexical decision on a proportion of the trials. These questions served to insure that the subject listened to the sentences for good comprehension.

Results and Discussion

Mean lexical decision times are presented in Table 2. There was effect of sentence type $F(1,17) = 10.27$, $p < .025$ reflecting the fact that lexical decisions were longer to targets in the final word condition. There was also an effect of rhyme $F(1,17) = 4.51$, $p < .05$ and no rhyme by length interaction. The rhyme effect was not, however, significant in an item analysis.

In contrast to experiment 1, rhyme priming obtained with seven intervening words. Furthermore, equivalent amounts of rhyme priming obtained when the target immediately followed the rhyming word and when seven words intervened. The result needs to be interpreted with considerable caution, however, because the effect of rhyme was not significant by items. With this caution in mind, the results suggest that listeners may hold onto the phonological form of a word when parsing demands make doing so an efficient strategy. Filler-gap constructions in which a number of words intervene between the gap and the filler appear to be one example where listeners use this strategy. Whether or not, there are other such constructions remains an important issue for future research.

Experiments 1 and 2 have demonstrated that the phonological code for a word is accessed during listening and that it remains active for at least

four words. Under special circumstances, the phonological code may also be held onto for as long as seven words. Experiment 3 examined whether or not the same results hold for reading.

Experiment 3

Subjects. Twenty-eight Wayne State University students served as subjects.

Method. The design and materials were similar to Experiment 1 with one change. A condition was added in which the word in the sentence that rhymed with target was presented at the end of the sentence. The sentences were presented on the CRT of an Apple mirco-computer using RSVP presentation. Presentation rate was 150 words per minute. Each word was presented for 350 msec with a 50 msec delay between words. The final word of the sentence was displayed with a period. The target followed the final word in the sentence and was bracketed in asterisks.

Results and Discussion

The results are presented in Table 3. There was a significant effect of length $F(1,27) = 6.89$, p .05 and a significant clause by length interaction $F(1,27) = 11.05$, p .01 in the subject analysis. Neither of these effects, however, approached significance by item. More importantly there were no significant effects of rhyme and no rhyme by length interactions in either the subject or the item analysis. Moreover, no rhyme priming obtained even when the sentence ended with a word that rhymed with the following target.

The results of Experiment 3 are somewhat surprising in light of the results of experiments 1 and 2. In these two experiments lexical decisions to a target word were facilitated when a rhyming word was embedded in the

preceding sentence. In experiment 3, with visual presentation, no rhyme priming effects obtained. There would seem to be two explanations for these results. One possibility is that listeners do not typically access speech-based codes in reading. Thus rhyme priming did not obtain because the phonological code for the prime word was never accessed. The rhyme priming obtained with visual primes in single word studies is then a special purpose strategy. A second possibility is that speech-based codes were accessed for the sentences, however, phonological information was not used in making the lexical decision. Other recent studies have suggested that sound-based information is not always used in making lexical decisions (e.g., Coltheart, 1978; Seidenberg, Barnes, and Tanenhaus, Note 1). Regardless of which explanation is correct future research is necessary to further understand the differences between single word studies and the present results and the differences between reading and listening obtained here.

General Discussion

The present studies were conducted in order to explore the utility of lexical rhyme priming as a methodology for tracing the access and maintenance of speech-based codes during listening and reading. The results, although by no means definitive, are encouraging. Experiment 1 demonstrated that cross-modal rhyme priming which has recently been observed in single word studies also obtains in studies in which a word rhyming with a target is embedded in a sentence. The results further suggested that in listening the sound-based code for a word remains active for at least four words. It was suggested that the length of time for which a sound-based code remains available may place constraints on the size of the chunking units used in processing

sentences. It is interesting in this respect to note that recent parsing models (e.g., Frazier and Fodor, 1978) assume that the initial syntactic analysis of a sentence is performed on units of approximately four words. The results of Experiment 2 suggested that under special circumstances, speech-based codes may be held onto longer. The results of this experiment lend support to Slowiacek and Clifton's (1980) suggestion that speech-based codes may play an important role in sentence parsing. Taken together then, the results of Experiment 2 suggest that speech-based codes are assessed in listening; these codes remain active for several words; and that the duration in which they remain active may depend upon the comprehension demands made on the listener.

Unfortunately, however, the results of the listening studies did not generalize to reading. In particular we were unable to find evidence of rhyme priming when the sentence containing the word rhyming with the target was presented visually. The interpretation of this null result remains unclear. Two hypotheses were suggested. One was that speech-based codes are not typically accessed in reading. The other was that subjects in the reading conditions were not using a phonological strategy in making lexical decisions. Recent research has shown that whether or not speech-based information is used in making lexical decisions is strategy dependent. If subjects were not using speech-based codes to make the lexical decision to the target then rhyme priming would not be observed even if speech-based codes were accessed in reading the sentence. Further research is clearly warranted before we can decide which of these alternative explanations is correct.

Reference Note

1. Seidenberg, M. S., Barnes, M. A., & Tanenhaus, M. K. Spelling-sound correspondences in reading: Influence of regularity, frequency, and task (Ms., McGill University).

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Table 1

Mean Lexical Decision Times (msec) for Experiment 1

Condition	Stimulus Sentences and Targets		Experiment 1 (Auditory)		
	Sentence	Target	Rhyme	Nonrhyme	Facilitation NR-R
First Clause					
4 Intervening Words	Since Jane forgot to put in all the {cream, / milk,} the cake was dry.	theme	696	730	+34
7 Intervening Words	If the pitch was a {ball, / strike,} the other team would win the game.	haul	713	717	+4
Second Clause					
4 Intervening Words	Because the murder left no clues, the {sleuth / cop} couldn't crack the case.	booth	681	702	+21
7 Intervening Words	The thief got away but the {purse / fur} was soon found in the back alley.	verse	696	698	+2

Note. By subjects, all factors are crossed.
By items, items are crossed by rhyme and by length and are nested within clause.

Table 2

Mean Lexical Decision Times (msec) for Experiment 2

Condition	Stimulus Sentences and Targets		Experiment 2 (WH-structure)		
	Sentence	Target	Rhyme	Nonrhyme	Facilitation NR-R
WH-Structure	The man was surprised at which {beer / wine} the judges awarded the first prize to ( ).	FEAR	599	622	+23
Prime	The old man looked {pale. / weak.}	JAIL	626	649	+23

Table 3

Mean Lexical Decision Times (msec) for Experiment 3

Condition	Stimulus Sentences and Targets		Experiment 3 (Visual)		
	Sentence	Target	Rhyme	Nonrhyme	Facilitation NR-R
First Clause					
4 Intervening Words	Since Jane forgot to put in all the {cream, / milk,} the cake was dry.	theme	912	889	-23
7 Intervening Words	If the pitch was a {ball, / strike} the other team would win the game.	haul	845	864	+19
Second Clause					
4 Intervening Words	Because the murder left no clues, the {sleuth / cop} couldn't crack the case.	booth	866	864	-2
7 Intervening Words	The thief got away but the {purse / fur} was soon found in the back alley.	verse	876	848	-28
0 Intervening Words	The old man looked {pale. / weak.}	jail	913[a]	917	+4

Note. By subjects, all factors are crossed.
By items, items are crossed by rhyme and by length and are nested within clause.

a A t-test indicated no difference between the rhyme and nonrhyme.